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(54) **POWER PLANT GENERATION SYSTEM, METHOD FOR CONTROLLING WIND TURBINE GENERATORS, POWER PLANT CONTROLLER AND WIND TURBINE GENERATOR**

KRAFTWERKGENERATORSYSTEM, VERFAHREN ZUR STEUERUNG VON
WINDTURBINENGENERATOREN, KRAFTWERKSTEUERUNG UND
WINDTURBINENGENERATOR

SYSTÈME DE GÉNÉRATION DE CENTRALE, PROCÉDÉ DE COMMANDE DE GÉNÉRATEURS
ÉOLIENS, DISPOSITIF DE COMMANDE DE CENTRALE ET GÉNÉRATEUR ÉOLIEN

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Description**Field of the invention**

5 **[0001]** The present invention relates to power plant generation systems, methods for controlling wind turbine generators, power plant controllers and wind turbine generators.

Background

10 **[0002]** In a wind power plant comprising a plurality of wind turbine generators, a disturbance may cause the output voltages of the wind turbine generators to oscillate in an unacceptable dimension. Controlling schemes that allow stabilizing the output voltages within a short amount of time are desirable. US 2011/0313591 A1 and DE 102010056456 A1 are examples of controlling individual turbine voltage according to the internal grid layout.

15 **Summary of the Invention**

[0003] According to an embodiment, a power generation system according to claim 1 is provided comprising a wind power plant comprising a plurality of wind turbine generators and a power plant controller configured to signal, to at least a portion of the plurality of wind turbine generators, a voltage reference for the output voltage of the wind turbine generator wherein each wind turbine generator comprises a controller configured to control the wind turbine generator based on the voltage reference.

[0004] According to one embodiment, the power plant controller comprises a determiner configured to determine the voltage reference for each of the wind turbine generators.

25 **[0005]** According to one embodiment, the determiner is configured to individually determine a voltage reference for each of the wind turbine generators.

[0006] According to one embodiment, the determiner is configured to determine the voltage reference for each of the wind turbine generators based on a location of the wind turbine generator.

[0007] According to one embodiment, the determiner is configured to determine the voltage reference for each of the wind turbine generators based on a location of the wind turbine generator within the wind power plant.

30 **[0008]** According to the invention the determiner is configured to determine the voltage reference in response to a (e.g. small) voltage disturbance in the wind power plant and is configured to determine the voltage reference for each of the wind turbine generators based on a location of the wind turbine generator with respect to a location of the (e.g. small) voltage disturbance.

[0009] According to one embodiment, the determiner is configured to determine the voltage reference based on a reactive power reference.

[0010] According to one embodiment, the power plant controller is further configured to signal, to at least a portion of the plurality of wind turbine generators, an active power reference for the active power output by the wind turbine generator and wherein the controller of each wind turbine generator is further configured to control the wind turbine generator in accordance with the active power reference.

40 **[0011]** According to one embodiment, the controller of each wind turbine generator is configured to control its output voltage in accordance with the reference voltage.

[0012] According to one embodiment, the controller of each wind turbine generator is configured to close-loop control its output voltage in accordance with the reference voltage.

45 **[0013]** According to one embodiment, the controller of each wind turbine generator is configured to control the wind turbine generator by controlling the stator voltage of the wind turbine generator based on the voltage reference.

[0014] According to one embodiment, the controller of each wind turbine generator is configured to control the wind turbine generator independent from the reactive power output by the wind turbine generator.

[0015] According to one embodiment, the controller of each wind turbine generator is configured to control the wind turbine generator independent from a reactive power reference.

50 **[0016]** According to other embodiment, a method for controlling wind turbine generators and a power plant controller corresponding to the power generation system described above are provided.

Brief Description of the Drawings

55 **[0017]** In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

[0018] In the following description, various embodiments of the invention are described with reference to the following

drawings, in which:

Figure 1 illustrates a common setup of a wind turbine.

Figure 2 illustrates an example of power generation system according to an embodiment.

Figure 3 shows a power generation system according to an embodiment.

Figure 4 shows a control arrangement.

Figure 5 shows a voltage diagram.

Figure 6 shows a power generation system according to an embodiment.

Figure 7 shows a flow diagram.

Figure 8 shows a control arrangement according to an embodiment.

Figure 9 shows a control arrangement according to an embodiment.

Figure 10 shows a voltage diagram.

Description

[0019] The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the invention. The various embodiments are not necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments.

[0020] Fig. 1 illustrates a common setup of a wind turbine 100 which may use the embodiments as described below. The wind turbine 100 is mounted on a base 1002. The wind turbine 100 includes a tower 1004 having a number of tower sections. A wind turbine nacelle 1006 is placed on top of the tower 1004. The wind turbine rotor includes a hub 1008 and at least one rotor blade 1010, e.g. three rotor blades 1010. The rotor blades 1010 are connected to the hub 1008 which in turn is connected to the nacelle 1006 through a low speed shaft which extends out of the front of the nacelle 1006.

[0021] Fig. 2 illustrates an example of power generation system 200 according to an embodiment.

[0022] A shaft 10 transfers mechanical energy from an energy source, for example the at least one rotor blade 1010 shown in Fig. 1, to a rotor of a variable speed generator 11. The shaft 10 is connected to the at least one rotor blade 1010 and is for example connected to the rotor via a gearbox in order to adapt the rotational speed of the shaft 10 (i.e. the speed of the wind turbine blades) to a speed range suitable for the generator 11. The generator 11 converts the mechanical energy provided via the shaft 10 into electrical energy and delivers the electrical energy at a set of stator terminals 12a, 12b, 12c. The generator 11 is in this example an interior permanent magnet (IPM) generator. The rotational speed of the shaft 10 varies as a function of the wind speed. Since the rotational speed of the rotor of the generator 11 is proportional to the rotational speed of the shaft 10, the amplitude and frequency of the voltage signal provided by the generator 11 at the stator terminals 12a, 12b, 12c varies in accordance with the rotational speed of the shaft 10. The terminals 12a, 12b, 12c of the generator 11 are connected to a generator side power converter 13.

[0023] The converter 13 for example comprises a set of switches in the form of, for example, MOSFETs, GTOs, IGBTs or BJTs.

[0024] The converter 13 functions, under normal operation, as an active rectifier converting the variable frequency AC voltage provided by the generator 11 into a DC voltage. The conversion may be controlled using a pulse width modulation (PWM) scheme, wherein control signals are applied to the switches of the converter 13 in order to provide the desired conversion functionality. In one embodiment, the switches are controlled by employing a space vector pulse width modulation scheme.

[0025] For a given speed of operation (i.e. a given rotor rotation speed), the electromagnetic power depends on the magnitude of the stator flux vector or stator current vector and its location with respect to the rotor flux vector. If the position of the rotor flux vector or stator current vector is known, it is possible to apply a voltage to the stator that positions the stator flux vector or stator current vector to give the desired magnitude of the power at a given rotational speed. Hence, by controlling the stator flux vector or stator current vector, the electromagnetic power, which corresponds to the power given to the load, can be obtained as desired.

[0026] The stator flux vector or stator current vector may for example be controlled by a suitable control of the generator side power converter 13. Accordingly, in one embodiment, the power generation system 200 includes a stator flux controller or stator current controller 20 which controls the generator side power converter 13 such that the power supplied by the electrical generator 11 to the power grid 18 has a desired magnitude.

[0027] The output of the converter 13 is connected to a DC link 14 which comprises a link capacitor for reducing the voltage ripple on the DC link.

[0028] The DC link 14 is connected to a grid side power converter 15. The topology of the grid side power converter 15 may be similar to the generator side power converter 13. The grid side power converter 15 for example normally

operates as an inverter for converting the DC voltage on the DC link 14 into a regulated AC voltage for feeding active and reactive power to a power grid 18.

[0029] The output of the grid side power converter 15 may be filtered by means of inductors 16a, 16b, and 16c in order to, for example, remove high order harmonics from the output power signal. The output power signal may, if needed, be filtered by a harmonic filter 17 in order to keep the interference or harmonic distortion at a low value. The output power signal is then provided to the power grid 18 via a transformer 19.

[0030] The wind turbine 100 and the power generation system 200 may be part of a power generation system including a plurality of wind turbines. This is illustrated in figure 3.

[0031] Figure 3 shows a power generation system 300 according to an embodiment.

[0032] The power generation system 300 includes a grid 301 for example corresponding to the grid 18 and a wind power plant 302. The wind power plant comprises a plurality of wind turbine generators 303 for example corresponding to the wind turbine 100 and the power generation system 200 without the grid 18. Specifically, each wind turbine generator 303 comprises a generator connection transformer 304 e.g. corresponding to the transformer 19 and each wind turbine generator 303 comprises a generator 305, e.g. corresponding to the components of the power generation system 200 on the generator side up to the transformer 19. Each wind turbine generator 303 further comprises a switch 306 via which it may be coupled to or decoupled from a collector bus 307 which collects the power generated by the wind turbine generators 303.

[0033] The collector bus 307 is coupled via a wind power plant transformer 308 to a point of common coupling (PCC) 309 which is coupled to the grid 301. (Reference signs 304, 305, 306 are only exemplarily shown for one of the wind turbine generators 303.)

[0034] The wind power plant further comprises a power plant controller 310 which may be supplied with a reference for the voltage at the PCC 309 V_{pccref} , a reference for the reactive power at the PCC 309 Q_{pccref} , i.e. a reference for the reactive power to be supplied by the wind power plant 302 and/or a reference for the active power at the PCC 309 P_{pccref} , i.e. a reference for the active power to be supplied by the wind power plant 302.

[0035] In the following, an example for the operation of the PPC is described with reference to figure 4.

[0036] Figure 4 shows a control arrangement 400.

[0037] The control arrangement 400 comprises a PPC 401 corresponding to PPC 310, a wind turbine generator controller 402, for example corresponding to the controller 20 of one of the wind turbine generators 303 and an internal network 403 corresponding to the generator 305 and the connection architecture of the generator 305 to the grid 301 for the power flow.

[0038] In this example, the PPC 401 receives a reference for the active power at the PCC 309 P_{pccref} and a reference for the voltage at the PCC 309 V_{pccref} and/or a reference for the reactive power at the PCC 309 Q_{pccref} . Further, the PPC 401 receives the reactive power measured at the PCC 309 $Q_{pccmeas}$ and/or the voltage measured at the PCC 309 $V_{pccmeas}$.

[0039] From this information, the PPC 401 generates an active power reference P_{ref} and a reactive power reference Q_{ref} and supplies these to the wind turbine generator controller 402.

[0040] The wind turbine generator controller 402 further receives the measured active power $P_{wtgmeas}$ and the measured reactive power $Q_{wtgmeas}$ as output by the generator 305. The wind turbine generator controller 402 may further receive the measured voltage at the output of the generator 305 $V_{wtgmeas}$.

[0041] Based on this information, the wind turbine generator controller 402 controls the generator 305, e.g. by setting the d axis stator reference voltage and the q axis stator reference voltage for the generator.

[0042] In the example shown in figure 4, the wind turbine generator controller 402 includes an active power and reactive power (P&Q) controller 404 generating a d axis stator current reference and a q axis stator current reference and an inner current control module 405 receiving the d axis stator current reference and the q axis stator current reference and generating the d axis stator reference voltage and the q axis stator reference voltage for the generator based on this input.

[0043] Alternatively, the wind turbine generator controller 402 may comprise a PI controller (not shown) generating a reference for the voltage at the output of the generator 305 from the reactive power reference and an active power and voltage (P&V) controller which generates the d axis stator current reference and the q axis stator current reference from the active power reference, a reference for the voltage at the output of the generator 305, the measured active power $P_{wtgmeas}$ output by the generator and the measured voltage at the output of the generator 305.

[0044] The PI controller can be seen as realizing an outer reactive power control loop which determines the voltage reference for the wind turbine generator inner controller.

[0045] In a weak grid connection a small disturbance occurring in the grid 301 can make the generator terminal voltage (i.e. at the terminals of the generators 305) oscillate in an unacceptable dimension. A controlling scheme as described with reference to figure 4 may not be able to handle this situation.

[0046] For example, after a large disturbance (FRT: Fault Ride Through), a coordinated FRT strategy between the 401 PPC and the wind turbine generator (WTG) controller 402 may force the PPC to be frozen until all WTGs 303 are

out of their FRT modes.

[0047] However, the WTGs 303 typically do not step out of their FRT modes simultaneously. The WTGs farthest to the fault location typically step out of FRT mode early and those close to the fault location typically step out later. Those WTGs 303 which step out of the FRT modes early do not receive the reactive power reference Q_{ref} from the PPC 401 because the PPC 401 is still frozen during that period. Thus these WTGs 303 control their reactive power based on a pre-fault reactive power setting. However, the grid impedance may be changed if the transmission system is reconfigured. As a consequence, the original reactive power reference may not be appropriate for the new operating point.

[0048] As a consequence of the above, the wind power plant and the wind turbine generators may experience very large voltage oscillation and become unstable and retrigger the FRT modes continuously.

[0049] An example for a behavior of a wind turbine generator is shown in figure 5.

[0050] Figure 5 shows a voltage diagram 500.

[0051] The voltage diagram 500 shows the voltage (in p.u.) over time at the low voltage side (i.e. the generator side) of the generator connection transformer 304 of a wind turbine generator 303. A first graph 501 shows the voltage for an SCR (short circuit ratio) of 1.6, a second graph 502 shows the voltage for an SCR (short circuit ratio) of 3.5 and a third graph 503 shows the voltage for an SCR (short circuit ratio) of 5.0. The example is based on a ratio of inductivity to resistance of the grid 301 of 10.

[0052] In this example, a disturbance at time $t = 2$ leads to persistent overvoltages which may for example be caused by a reactive power reference not being appropriate for the post-disturbance condition.

[0053] Possible disturbances that can lead a WTG with reactive power controller and current slow PPC voltage controller into voltage instability in a weak grid connection are

1. when the grid load is suddenly connected or disconnected
2. when a fault has happened in the external grid and a voltage dip follows up in the wind power plant network. During the fault recovery period, it may be difficult to coordinate between the PPC and the WTG.
3. when grid impedance is decreased after fault clearances.

[0054] Under these conditions, the pre-disturbance reactive power reference for WTG may be improper for the post-disturbance condition. As a consequence, the PPC 401 may not be fast enough to react and the WTG reactive power controller 402 cannot receive a correct reactive power reference. Finally a voltage instability may occur, and the WTG/WPP may enter FRT modes continuously.

[0055] According to one embodiment, the issues described above are addressed by a local fast WTG voltage controller together with a proper coordination with the PPC voltage/reactive power controller.

[0056] Figure 6 shows a power generation system 600 according to an embodiment.

[0057] The power generation system 600 comprises a wind power plant comprising a plurality of wind turbine generators 601.

[0058] The power generation system 600 comprises a power plant controller 602 configured to signal, to at least a portion of the plurality of wind turbine generators 601 (e.g. to each of the wind turbine generators), a voltage reference 603 for the output voltage of the wind turbine generator 601.

[0059] Each wind turbine generator comprises a controller 604 configured to control the wind turbine generator based on the voltage reference.

[0060] Thus, according to one embodiment, a power plant controller of a wind power plant sends a voltage reference (i.e. an wind turbine generator output voltage reference) to the wind turbine generators of the wind power plant. In other words, the wind turbine generators are controlled by the power plant controller based on an output voltage reference instead of, for example, a reactive power reference as in the control arrangement 400 described above with reference to figure 4.

[0061] Embodiments allow ensuring the voltage stability in the wind power plant even when connected to a weak external grid. Further, embodiments allow reducing the size of additional reactive power compensation and thus allow reducing costs.

[0062] The various components of the power generation system such as the power plant controller, the determiner, the wind turbine generator controller etc. may for example be implemented by one or more circuits. A "circuit" may be understood as any kind of a logic implementing entity, which may be special purpose circuitry or a processor executing software stored in a memory, firmware, or any combination thereof. Thus, in an embodiment, a "circuit" may be a hard-wired logic circuit or a programmable logic circuit such as a programmable processor, e.g. a microprocessor (e.g. a Complex Instruction Set Computer (CISC) processor or a Reduced Instruction Set Computer (RISC) processor). A "circuit" may also be a processor executing software, e.g. any kind of computer program, e.g. a computer program using a virtual machine code such as e.g. Java.

[0063] The power plant controller for example comprises a determiner configured to determine the voltage reference for each of the wind turbine generators.

[0064] The determiner is for example configured to individually determine a voltage reference for each of the wind turbine generators.

[0065] The determiner is for example configured to determine the voltage reference for each of the wind turbine generators based on a location of the wind turbine generator.

[0066] For example, the determiner is configured to determine the voltage reference for each of the wind turbine generators based on a location of the wind turbine generator within the wind power plant.

[0067] The determiner may be configured to determine the voltage reference in response to a (e.g. small) disturbance in the wind power plant and is configured to determine the voltage reference for each of the wind turbine generators based on a location of the wind turbine generator with respect to a location of the (e.g. small) disturbance.

[0068] The determiner may be configured to determine the voltage reference based on a reactive power reference.

[0069] In one embodiment, the power plant controller is further configured to signal, to at least a portion of the plurality of wind turbine generators, an active power reference for the active power output by the wind turbine generator and wherein the controller of each wind turbine generator is further configured to control the wind turbine generator in accordance with the active power reference.

[0070] The controller of each wind turbine generator is for example configured to control its output voltage in accordance with the reference voltage.

[0071] For example, the controller of each wind turbine generator is configured to close-loop control its output voltage in accordance with the reference voltage.

[0072] In one embodiment, the controller of each wind turbine generator is configured to control the wind turbine generator by controlling the stator voltage of the wind turbine generator based on the voltage reference.

[0073] The controller of each wind turbine generator is for example configured to control the wind turbine generator independent from the reactive power output by the wind turbine generator. In other words, the controller for example does not receive the reactive power output by the wind turbine generator as input for the control procedure.

[0074] The controller of each wind turbine generator is for example configured to control the wind turbine generator independent from a reactive power reference.

[0075] The power generation system 600 for example carries out a method as illustrated in figure 7.

[0076] Figure 7 shows a flow diagram 700.

[0077] The flow diagram 700 illustrates a method for controlling wind turbine generators.

[0078] In 701, to at least a portion of the plurality of wind turbine generators of a plurality of wind turbine generators of a wind power plant, a voltage reference for the output voltage of the wind turbine generator is signaled.

[0079] In 702, each wind turbine generator is controlled based on the voltage reference signaled to the wind turbine generator.

[0080] According to other embodiment, a power plant controller and a wind turbine generator corresponding to the power generation system described with reference to figure 6 are provided. It should be noted that embodiments described in context of the power generation system are analogously valid for the method described with reference to figure 7, the power plant controller and the wind turbine generator and vice versa.

[0081] In the following, a control scheme for a wind power plant is described in more detail.

[0082] Figure 8 shows a control arrangement 800 according to an embodiment.

[0083] The control arrangement 800 comprises a PPC 801 corresponding to PPC 310, a wind turbine generator controller 802, for example corresponding to the controller 20 of one of the wind turbine generators 303 and an internal network 803 corresponding to the generator 305 and the connection architecture of the generator 305 to the grid 301 for the power flow.

[0084] In this example, the PPC 801 receives a reference for the active power at the PCC 309 P_{pccref} and a reference for the voltage at the PCC 309 V_{pccref} or a reference for the reactive power at the PCC 309 Q_{pccref} . Further, the PPC 801 receives the voltage measured at the PCC 309 $V_{pccmeas}$ or the measured reactive power at the PCC 309 $Q_{pccmeas}$, respectively.

[0085] The PPC 801 comprises a power controller 804 which generates an active power reference P_{ref} and a reactive power reference Q_{ref} from the information received by the PPC 801. The PPC 801 further comprises an inverse droop controller 807 which is supplied with the reactive power reference Q_{ref} and generates a voltage reference (i.e. a wind turbine generator output voltage reference) V_{wtgref} . The active power reference and the voltage reference are communicated to the wind turbine generator controller 802. The wind turbine generator controller 802 further receives the measured active power $P_{wtgmeas}$ and the measured the measured voltage $V_{wtgmeas}$ at the output of the generator 305.

[0086] The wind turbine generator controller 802 includes a P&V controller 805 generating a d axis stator current reference and a q axis stator current reference based on the received information. The wind turbine generator controller 802 further includes an inner current control module 806 receiving the d axis stator current reference and the q axis stator current reference and generating the d axis stator reference voltage and the q axis stator reference voltage for the generator based on this input.

[0087] The P&V controller 805 may for example determine the d axis stator current reference $I_{d,ref}$ and the q axis stator

current reference $I_{q,ref}$ according to the following:

$$I_{d,ref} = \left(k_{p,id} + \frac{k_{i,id}}{s} \right) (V_{wtgref} - V_{wtgmeas})$$

$$I_{q,ref} = \left(k_{p,iq} + \frac{k_{i,iq}}{s} \right) (V_{DCref}^2 - V_{DCmeas}^2)$$

where $k_{p,id}$ (proportional gain), $k_{i,id}$ (integrator gain), $k_{p,iq}$ (proportional gain) and $k_{i,iq}$ (integrator gain) are control parameters and $1/s$ represents integration (complex-s domain). V_{DCref} is a reference voltage for the DC link 14 and V_{DCmeas} is the measured voltage of the DC link 14.

[0088] The inner current control module 806 for example determines the d axis stator reference voltage $V_{d,ref}$ and the q axis stator reference voltage $V_{q,ref}$ according to the following:

$$V_{d,ref} = \left(k_{p,vd} + \frac{k_{i,vd}}{s} \right) (I_{d,ref} - I_{d,meas}) + V_{d,meas} - L\omega I_{q,meas}$$

$$V_{q,ref} = \left(k_{p,vq} + \frac{k_{i,vq}}{s} \right) (I_{q,ref} - I_{q,meas}) + V_{q,meas} + L\omega I_{d,meas}$$

where $k_{p,vd}$ (proportional gain), $k_{i,vd}$ (integrator gain), $k_{p,vq}$ (proportional gain), $k_{i,vq}$ (integrator gain) are control parameters, $1/s$ represents integration (complex-s domain) L is the inductance of the filter between the generator 11 and the stator terminals 12a, 12b, 12c and ω is the frequency of the stator current.

[0089] The inverse droop controller 807 for example determines the voltage reference V_{wtgref} for example such that

$$V_{wtgref} - V_{ref,0} = k_{droop} (Q_{ref} - Q_{ref,0})$$

where

$V_{ref,0}$ is the internal WTG voltage reference setpoint, $Q_{ref,0}$ is the internal WTG reactive power reference setpoint. These two parameters may for example be estimated based on the power flow study.

[0090] The PPC 804 for example determines the reactive power reference Q_{ref} according to the following:

$$Q_{ref} = \left(k_{p,Qpcc} + \frac{k_{i,Qpcc}}{s} \right) (V_{pcc,ref} - V_{pcc,meas})$$

where $k_{p,Qpcc}$ (proportional gain) and $k_{i,Qpcc}$ (integrator gain) are control parameters and $1/s$ represents integration (complex-s domain).

[0091] It should be noted that in this embodiment, the wind turbine generator controller does not have an outer reactive power control loop, in contrast to the control arrangement 400 described with reference to figure 4.

[0092] In the power generation system 300, the PPC 310, i.e. a controller on wind power plant (i.e. wind farm) level may send the voltage reference to each WTG 303.

[0093] In the example of figure 8, each wind turbine generator 303 may be supplied with the same voltage reference. In the following, an embodiment is described in which each wind turbine generator 303 is supplied with an individual voltage reference.

[0094] Figure 9 shows a control arrangement 900 according to an embodiment.

[0095] Similarly to the control arrangement 800, the control arrangement 900 comprises a PPC 901 corresponding to PPC 310, a wind turbine generator controller 902, for example corresponding to the controller 20 of one of the wind

turbine generators 303 and an internal network 903 corresponding to the generator 305 and the connection architecture of the generator 305 to the grid 301 for the power flow.

[0096] The PPC 901 receives a reference for the active power at the PCC 309 P_{pccref} . Further, the PPC 901 receives a reference for the voltage at the PCC 309 V_{pccref} and the voltage measured at the PCC 309 $V_{pccmeas}$. Alternatively, the PPC 901 further receives a reference for the reactive power at the PCC 309 Q_{pccref} and the measured reactive power output by the wind turbine generator $Q_{pccmeas}$.

[0097] The PPC 901 comprises a power controller which generates an active power reference P_{ref} and a reactive power reference Q_{ref} from the information received by the PPC 901.

[0098] The PPC 901 further comprises an inverse droop controller 907 which is supplied with the reactive power reference Q_{ref} and generates a voltage reference (i.e. a wind turbine generator output voltage reference) increment ΔV_{wtgref} . Further, the PPC 901 comprises an adder 908 configured to add an individual base voltage reference $V_{0wtgref,i}$ to the voltage reference increment ΔV_{wtgref} to generate an individual voltage reference $V_{wtgref,i}$.

[0099] The individual base voltage reference $V_{0wtgref,i}$ is for example determined for a wind turbine generator (with index i) 303 based on its location in the wind power plant 302, e.g. based on a minimum total active power loss criterion. With equal voltage references for the WTGs 303 it may happen that one WTG 303 injects reactive power while another absorbs reactive power which may result in a decrease of the total WPP reactive power capability at the PCC 309. Further, the total WPP active power loss may not be minimal since the power flow within WPP is not minimized.

[0100] The active power reference and the individual voltage reference are communicated to the wind turbine generator controller 902.

[0101] The wind turbine generator controller 902 further receives the measured active power $P_{wtgmeas}$ and the measured the measured voltage at the output of the generator 305 $V_{wtgmeas}$.

[0102] The wind turbine generator controller 902 includes a P&V controller 905 generating a d axis stator current reference and a q axis stator current reference based on the received information. The wind turbine generator controller 902 further includes an inner current control module 906 receiving the d axis stator current reference and the q axis stator current reference and generating the d axis stator reference voltage and the q axis stator reference voltage for the generator based on this input.

[0103] In an alternative embodiment, the inverse droop controller 907 and the adder 908 may be omitted from the PPC 901 and the wind turbine generator controller 902 may include functionally equivalent elements. Thus, for example, the reactive power reference Q_{ref} is fed to a PI controller (not shown) in the wind turbine generator controller 902, the PI controller generates a wind turbine generator output voltage reference increment (corresponding to ΔV_{wtgref}) and an adder (not shown) in the wind turbine generator controller 902 adds an individual base voltage reference (corresponding to $V_{0wtgref,i}$) to the voltage reference increment to generate an individual voltage reference (corresponding to $V_{wtgref,i}$). The P&V controller 905 generates the d axis stator current reference and the q axis stator current reference based on the individual voltage reference, the active power reference P_{ref} , and the measured active power $P_{wtgmeas}$ and the measured voltage $V_{wtgmeas}$ output by the generator 305.

[0104] In the following, the handling of (e.g. small) disturbances by a controlling scheme according to an embodiment, for example the controlling schemes as described with reference to figures 8 and 9 are illustrated.

[0105] Figure 10 shows a voltage diagram 1000.

[0106] The voltage diagram 1000 shows the voltage (in p.u.) over time at the low voltage side of the generator connection transformer 304 of a wind turbine generator 303. A first graph 1001 shows the voltage for an SCR (short circuit ratio) of 1.6, a second graph 1002 shows the voltage for an SCR (short circuit ratio) of 3.5 and a third graph 1003 shows the voltage for an SCR (short circuit ratio) of 5.0.

[0107] The example is based on a ratio of inductivity to resistance of the grid of 10. Further, the reference voltage is shown by a fourth graph 1004.

[0108] In this example, a disturbance at time $t = 2$ leads to overvoltages which are quickly brought back to the level of the reference voltage such that the wind power plant is quickly in a stable condition.

[0109] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the scope of the invention as defined by the appended claims.

Claims

1. A power generation system comprising
 - a wind power plant comprising a plurality of wind turbine generators;
 - a power plant controller configured to signal, to each of at least a portion of the plurality of wind turbine generators, a voltage reference for the output voltage of the wind turbine generator, wherein the power plant controller comprises a determiner configured to determine the voltage reference in response to a voltage disturbance in the wind power

plant grid and is configured to determine the voltage reference for each of the at least a portion of the plurality of the wind turbine generators based on a location of the wind turbine generator with respect to a location of the voltage disturbance in the wind power plant grid;

wherein each of the at least a portion of the plurality of wind turbine generators comprises a controller configured to control the wind turbine generator based on the voltage reference.

2. The power generation system according to claim 1, wherein the determiner is configured to individually determine a voltage reference for each of the at least a portion of the plurality of the wind turbine generators.

3. The power generation system according to claim 1, wherein the determiner is configured to determine the voltage reference based on a reactive power reference.

4. The power generation system according to claim 1, wherein the power plant controller is further configured to signal, to each of the at least a portion of the plurality of the wind turbine generators, an active power reference for the active power output by the wind turbine generator and wherein the controller of each of the at least a portion of the plurality of wind turbine generators is further configured to control the wind turbine generator in accordance with the active power reference.

5. The power generation system according to claim 1, wherein the controller of each of the at least a portion of the plurality of wind turbine generators is configured to control its output voltage in accordance with the reference voltage.

6. The power generation system according to claim 1, wherein the controller of each of the at least a portion of the plurality of wind turbine generators is configured to close-loop control its output voltage in accordance with the reference voltage.

7. The power generation system according to claim 1, wherein the controller of each of the at least a portion of the plurality of wind turbine generators is configured to control the wind turbine generator by controlling the stator voltage of the wind turbine generator based on the voltage reference.

8. The power generation system according to claim 1, wherein the controller of each of the at least a portion of the plurality of wind turbine generators is configured to control the wind turbine generator independent from the reactive power output by the wind turbine generator.

9. The power generation system according to claim 1, wherein the controller of each of the at least a portion of the plurality of wind turbine generators is configured to control the wind turbine generator independent from a reactive power reference.

10. A method for controlling wind turbine generators comprising

- signalling, to each wind turbine generator of at least a portion of a plurality of wind turbine generators of a wind power plant, a voltage reference for the output voltage of the wind turbine generator, the voltage reference for each of the at least a portion of the plurality of the wind turbine generators being based on a location of the wind turbine generator with respect to a location of a voltage disturbance in the wind power plant grid; and
- controlling the wind turbine generator based on the voltage reference signaled to the wind turbine generator.

11. A power plant controller comprising

- a determiner configured to determine, for each wind turbine generator of at least a portion of a plurality of wind turbine generators of a wind power plant, a voltage reference for the output voltage of the wind turbine generator, the voltage reference for each of the at least a portion of the plurality of the wind turbine generators being based on a location of the wind turbine generator with respect to a location of a voltage disturbance in the wind power plant grid; and
- a transmitter configured to signal the voltage reference to the wind turbine generator.

Patentansprüche

1. Stromerzeugungssystem, umfassend

einen Windpark, der eine Mehrzahl von Windkraftanlagen umfasst;
 eine Parksteuervorrichtung, die konfiguriert ist, um jeder von zumindest einem Teil der Mehrzahl von Windkraftanlagen einen Spannungsbezug für die Ausgangsspannung der Windkraftanlage zu signalisieren, wobei die Parksteuervorrichtung eine Bestimmungsvorrichtung umfasst, die konfiguriert ist, um den Spannungsbezug als Reaktion auf eine Spannungsstörung in dem Windparknetz zu bestimmen und die konfiguriert ist, um den Spannungsbezug für jede von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen basierend auf einem Ort der Windkraftanlage in Bezug auf einen Ort der Spannungsstörung in dem Windparknetz zu bestimmen;
 wobei jede von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen eine Steuervorrichtung umfasst, die konfiguriert ist, um die Windkraftanlage basierend auf dem Spannungsbezug zu steuern.

2. Stromerzeugungssystem nach Anspruch 1, wobei die Bestimmungsvorrichtung konfiguriert ist, um einen Spannungsbezug für jede von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen individuell zu bestimmen.

3. Stromerzeugungssystem nach Anspruch 1, wobei die Bestimmungsvorrichtung konfiguriert ist, um den Spannungsbezug basierend auf einem Blindleistungsbezug zu bestimmen.

4. Stromerzeugungssystem nach Anspruch 1, wobei die Parksteuervorrichtung weiter konfiguriert ist, um jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen einen Wirkleistungsbezug für die Ausgangswirkleistung von der Windkraftanlage zu signalisieren, und wobei die Steuervorrichtung von jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen weiter konfiguriert ist, um die Windkraftanlage in Übereinstimmung mit dem Wirkleistungsbezug zu steuern.

5. Stromerzeugungssystem nach Anspruch 1, wobei die Steuervorrichtung von jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen konfiguriert ist, um deren Ausgangsspannung in Übereinstimmung mit der Bezugsspannung zu steuern.

6. Stromerzeugungssystem nach Anspruch 1, wobei die Steuervorrichtung von jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen konfiguriert ist, um deren Ausgangsspannung in Übereinstimmung mit der Bezugsspannung in einem geschlossenen Regelkreis zu steuern.

7. Stromerzeugungssystem nach Anspruch 1, wobei die Steuervorrichtung von jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen konfiguriert ist, um die Windkraftanlage durch ein Steuern der Statorspannung der Windkraftanlage basierend auf dem Spannungsbezug zu steuern.

8. Stromerzeugungssystem nach Anspruch 1, wobei die Steuervorrichtung von jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen konfiguriert ist, um die Windkraftanlage unabhängig von der Ausgangsblindleistung von der Windkraftanlage zu steuern.

9. Stromerzeugungssystem nach Anspruch 1, wobei die Steuervorrichtung von jeder von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen konfiguriert ist, um die Windkraftanlage unabhängig von einem Blindleistungsbezug zu steuern.

10. Verfahren zum Steuern von Windkraftanlagen, umfassend

- Signalisieren jeder Windkraftanlage von zumindest einem Teil von einer Mehrzahl von Windkraftanlagen eines Windparks einen Spannungsbezug für die Ausgangsspannung der Windkraftanlage, wobei der Spannungsbezug für jede von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen auf einem Ort der Windkraftanlage in Bezug auf einen Ort einer Spannungsstörung in dem Windparknetz basiert; und
- Steuern der Windkraftanlage basierend auf dem Spannungsbezug, der der Windkraftanlage signalisiert wird.

11. Parksteuervorrichtung, umfassend

- eine Bestimmungsvorrichtung, die konfiguriert ist, um für jede Windkraftanlage von zumindest einem Teil von einer Mehrzahl von Windkraftanlagen eines Windparks einen Spannungsbezug für die Ausgangsspannung der Windkraftanlage zu bestimmen, wobei der Spannungsbezug für jede von dem zumindest einen Teil der Mehrzahl von Windkraftanlagen auf einem Ort der Windkraftanlage in Bezug auf einen Ort einer Spannungsstörung in dem Windparknetz basiert; und

- einen Sender, der konfiguriert ist, um den Spannungsbezug einer Windkraftanlage zu signalisieren.

Revendications

1. Système de génération de courant comprenant une centrale éolienne comprenant une pluralité de générateurs éoliens ; un dispositif de commande de centrale électrique configuré pour signaler à chacun d'au moins une partie de la pluralité de générateurs éoliens une tension de référence pour la tension de sortie du générateur éolien, dans lequel le dispositif de commande de centrale électrique comprend un détermineur configuré pour déterminer la référence de tension en réponse à un trouble de la tension dans le réseau de la centrale éolienne et est configuré pour déterminer la référence de tension pour chacun de la au moins une partie de la pluralité de générateurs éoliens sur la base d'un emplacement du générateur éolien par rapport à un emplacement du trouble de tension dans le réseau de la centrale éolienne ; dans lequel chacun de la au moins une partie de la pluralité de générateurs éoliens comprend un dispositif de commande configuré pour commander le générateur éolien sur la base de la référence de tension.
2. Système de génération de courant selon la revendication 1, dans lequel le détermineur est configuré pour déterminer individuellement une référence de tension pour chacun de la au moins une partie de la pluralité des générateurs éoliens.
3. Système de génération de courant selon la revendication 1, dans lequel le détermineur est configuré pour déterminer la référence de tension sur la base d'une référence de puissance réactive.
4. Système de génération de courant selon la revendication 1, dans lequel le dispositif de commande de centrale de centrale électrique est en outre configuré pour signaler à chacun de la au moins une partie de la pluralité des générateurs éoliens une référence de puissance active pour la puissance active délivrée par le générateur éolien et dans lequel le dispositif de commande de chacun de la au moins une partie de la pluralité de générateurs éoliens est en outre configuré pour commander le générateur éolien conformément à la référence de puissance active.
5. Système de génération de courant selon la revendication 1, dans lequel le dispositif de commande de chacun de la au moins une partie de la pluralité de générateurs éoliens est configuré pour commander sa tension de sortie conformément à la tension de référence.
6. Système de génération de courant selon la revendication 1, dans lequel le dispositif de commande de chacun de la au moins une partie de la pluralité de générateurs éoliens est configuré pour commander en circuit fermé sa tension de sortie conformément à la tension de référence.
7. Système de génération de courant selon la revendication 1, dans lequel le dispositif de commande de chacun de la au moins une partie de la pluralité de générateurs éoliens est configuré pour commander le générateur éolien en commandant la tension statorique du générateur éolien sur la base de la référence de tension.
8. Système de génération de courant selon la revendication 1, dans lequel le dispositif de commande de chacun de la au moins une partie de la pluralité de générateurs éoliens est configuré pour commander le générateur éolien indépendamment de la puissance réactive délivrée par le générateur éolien.
9. Système de génération de courant selon la revendication 1, dans lequel le dispositif de commande de chacun de la au moins une partie de la pluralité de générateurs éoliens est configuré pour commander le générateur éolien indépendamment d'une référence de puissance réactive.
10. Procédé de commande de générateurs éoliens comprenant :
 - la signalisation à chaque générateur éolien d'au moins une partie d'une pluralité de générateurs éoliens d'une centrale éolienne, d'une référence de tension pour la tension de sortie du générateur éolien, la référence de tension pour chacun d'au moins une partie de la pluralité des générateurs éoliens étant basée sur un emplacement du générateur éolien par rapport à un emplacement d'un trouble de tension dans le réseau de la centrale éolienne ; et
 - la commande du générateur éolien sur la base de la référence de tension signalée au générateur éolien.

11. Dispositif de commande de centrale électrique comprenant :

- un détermineur configuré pour déterminer pour chaque générateur éolien d'au moins une partie d'une pluralité de générateurs éoliens d'une centrale éolienne une référence de tension pour la tension de sortie du générateur éolien, la référence de tension pour chacun d'au moins une partie de la pluralité des générateurs éoliens étant basée sur un emplacement du générateur éolien par rapport à un emplacement d'un trouble de tension dans le réseau de centrale éolienne ; et
- un transmetteur configuré pour signaler la référence de tension au générateur éolien.

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FIG 1

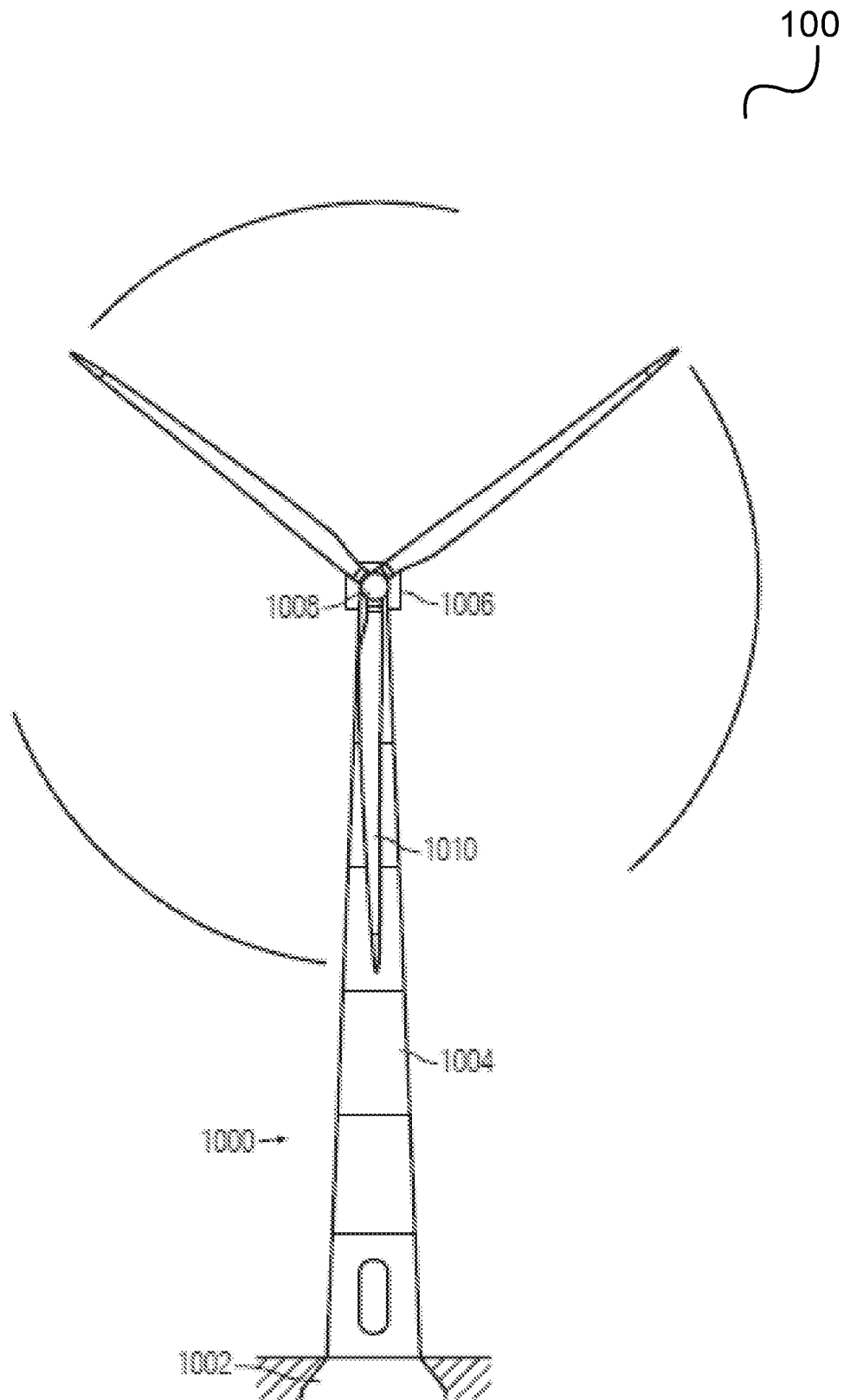


FIG 2

200

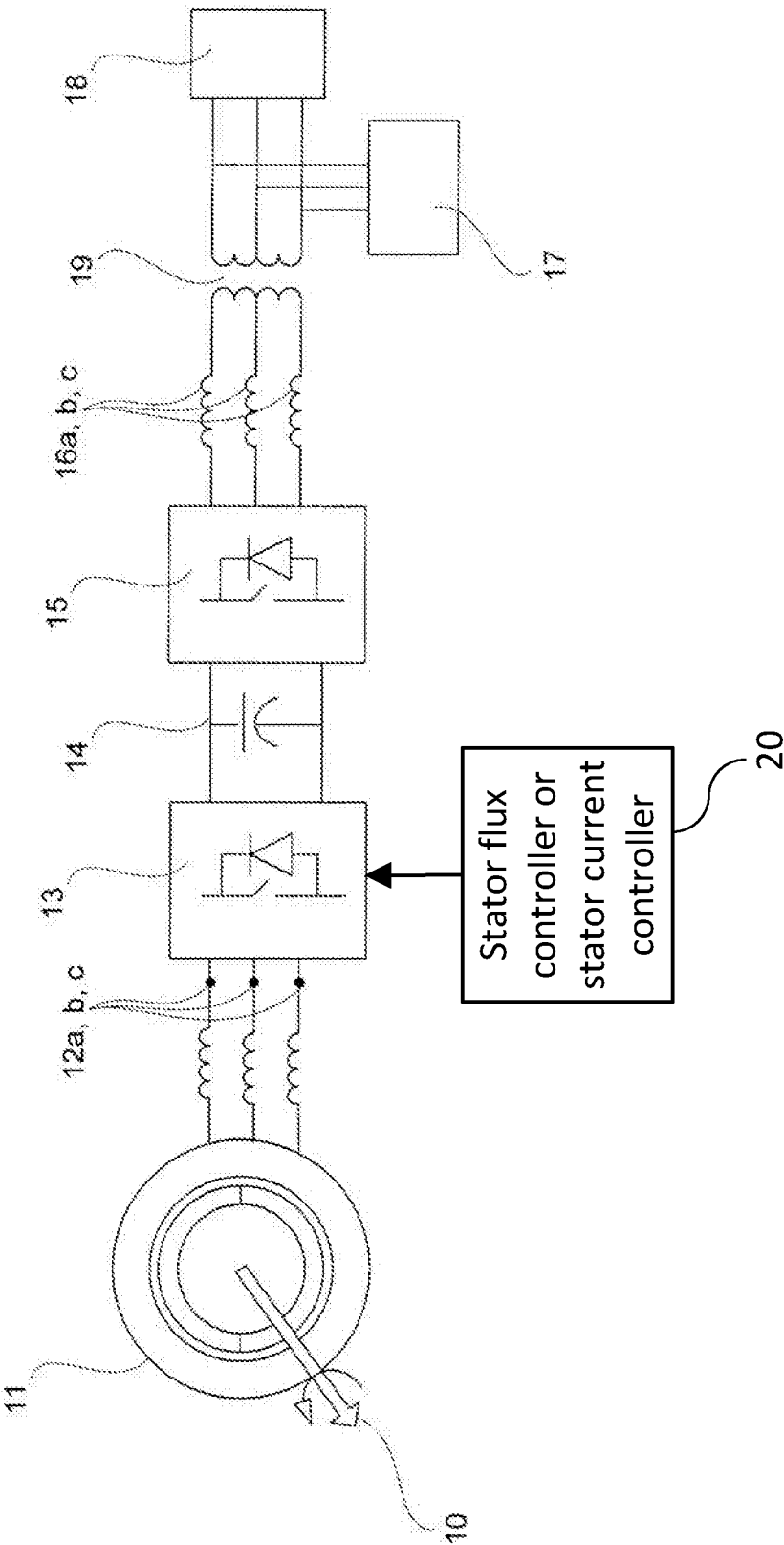
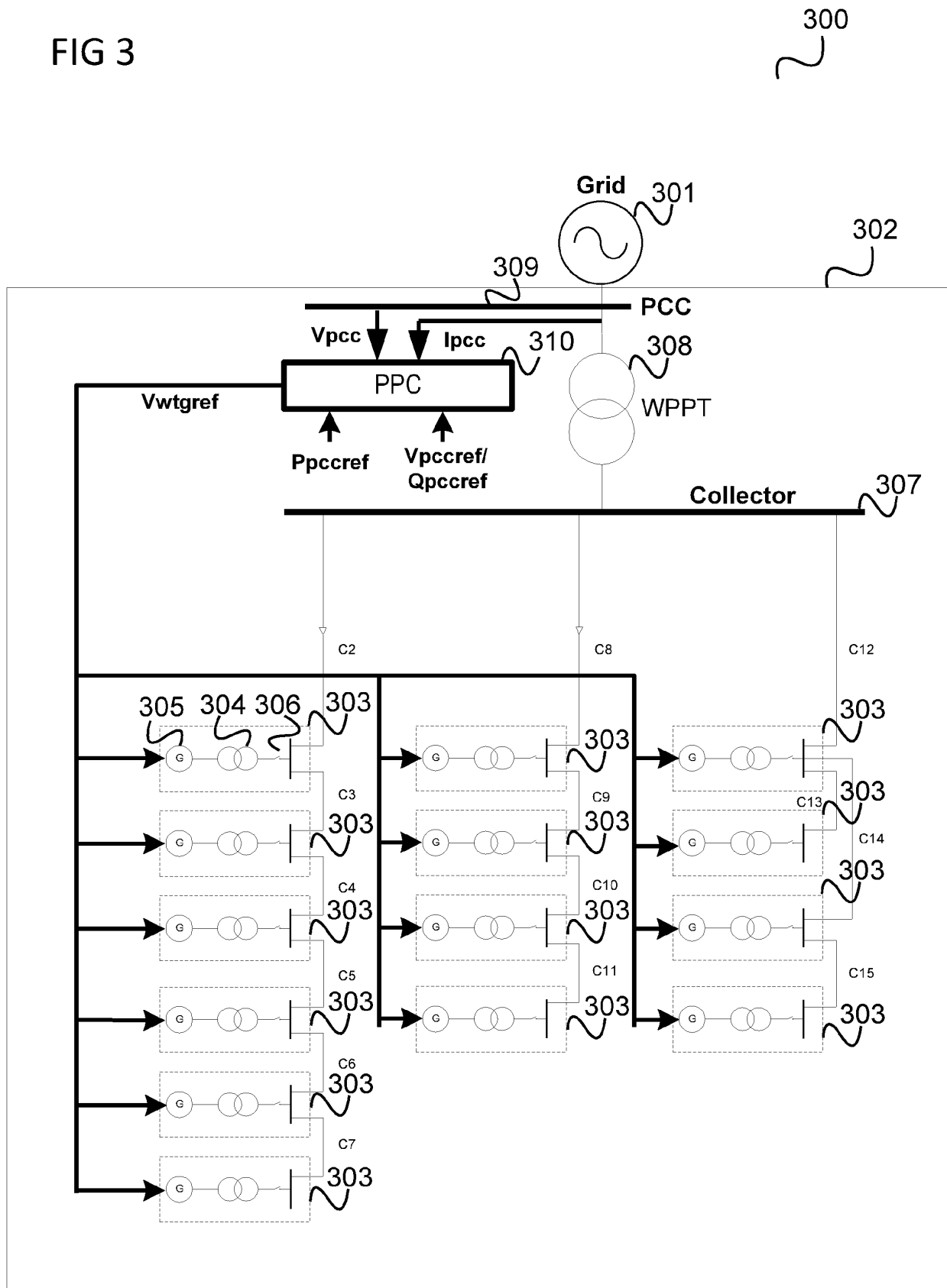


FIG 3



400

FIG 4

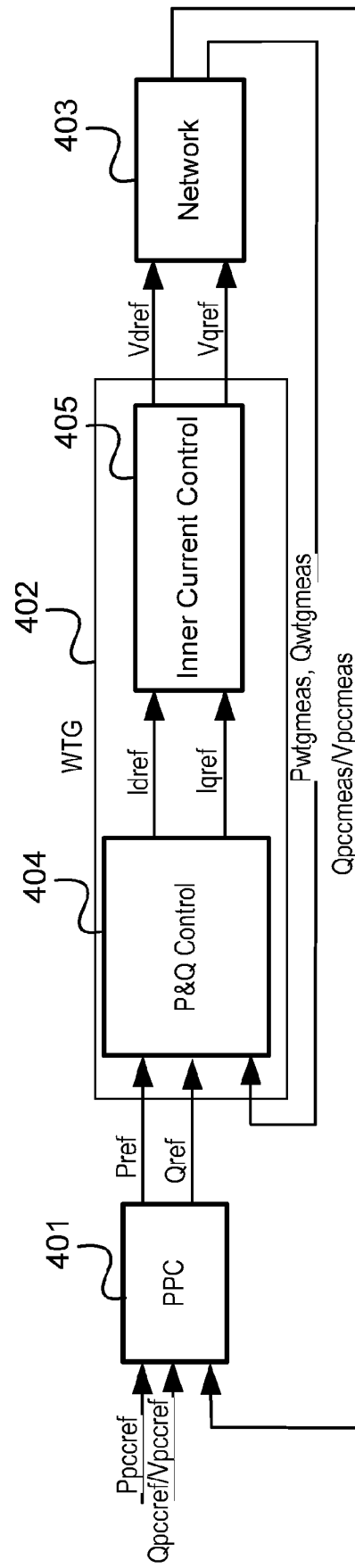


FIG 5

500

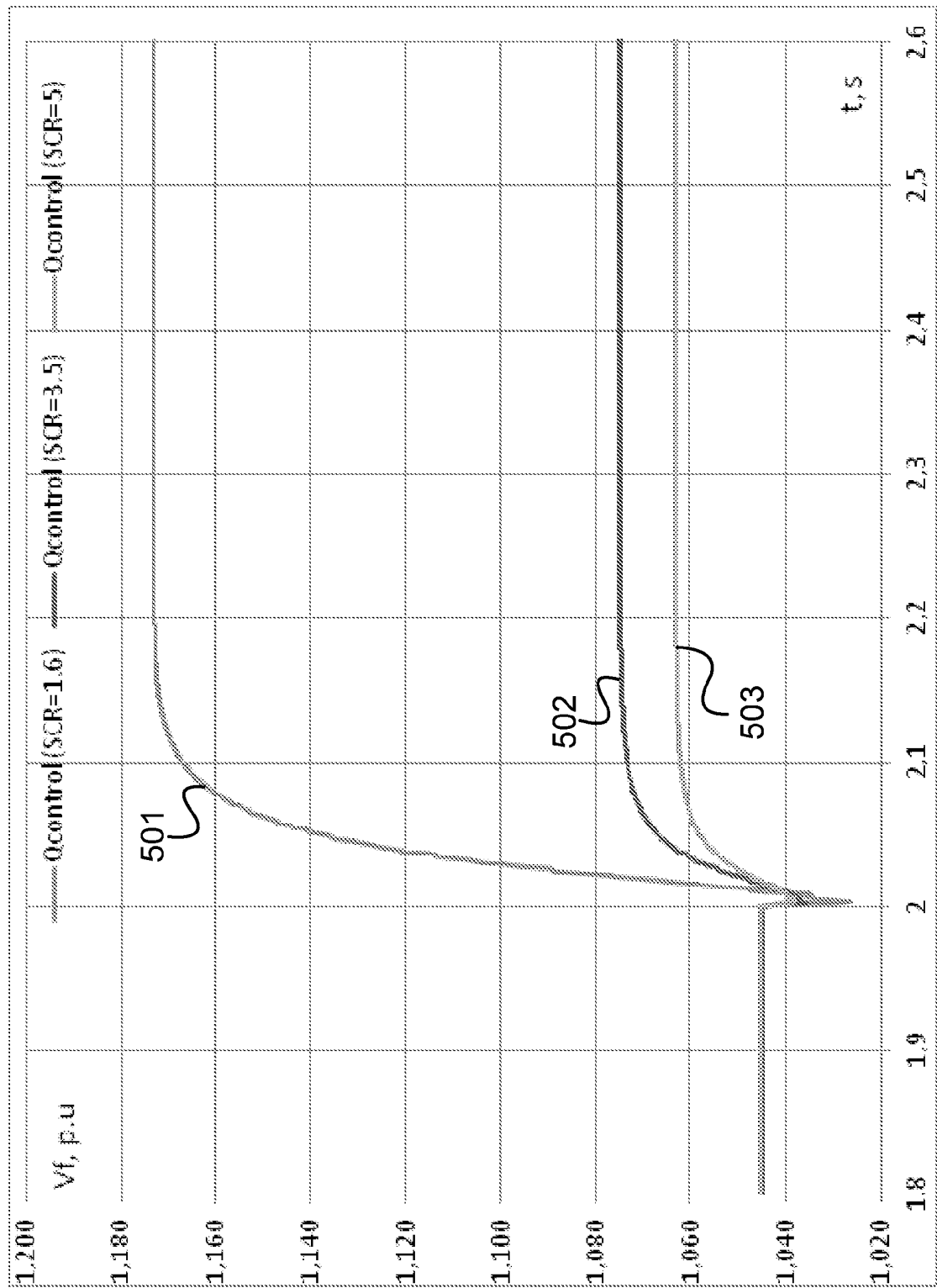


FIG 6

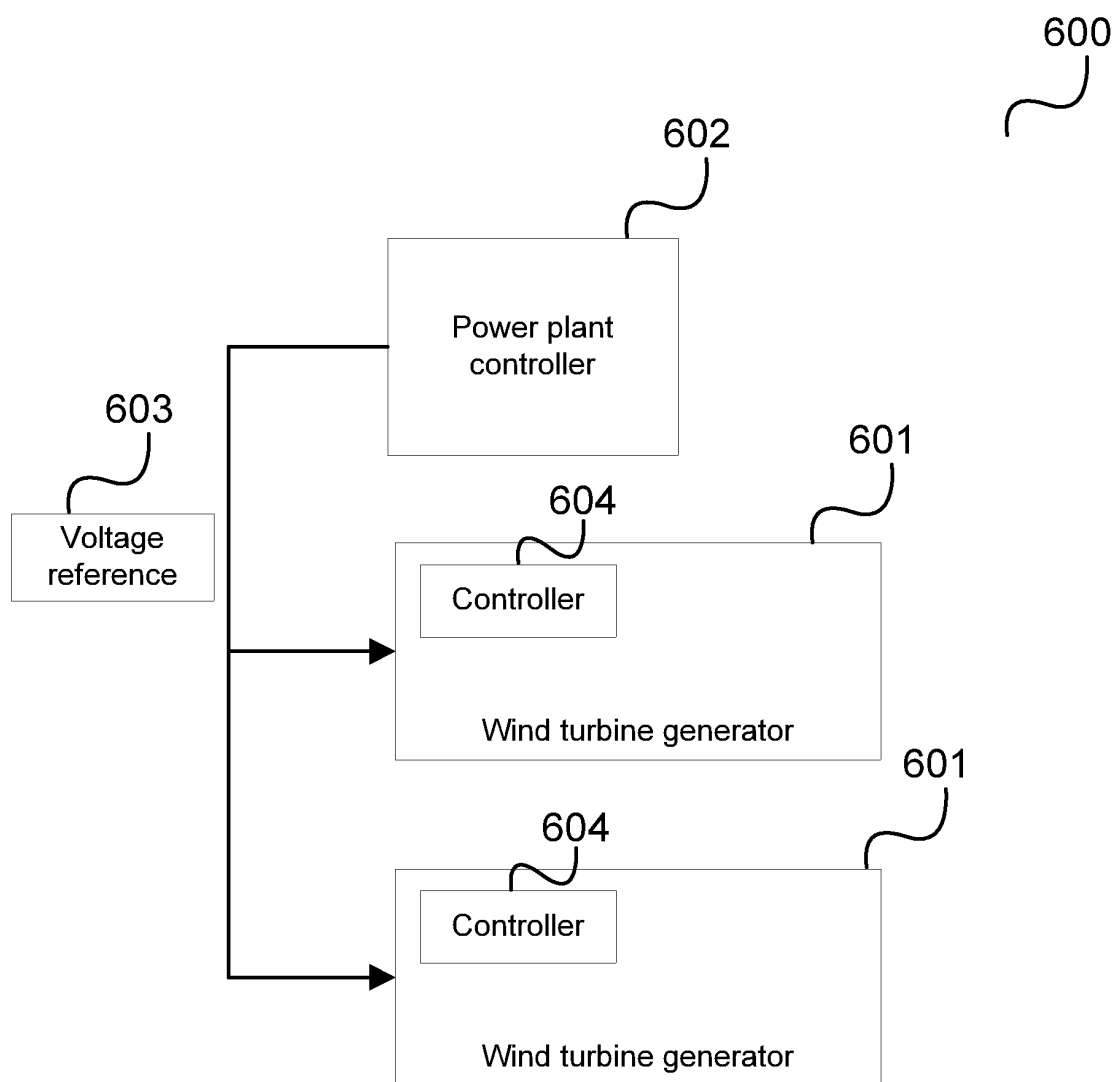
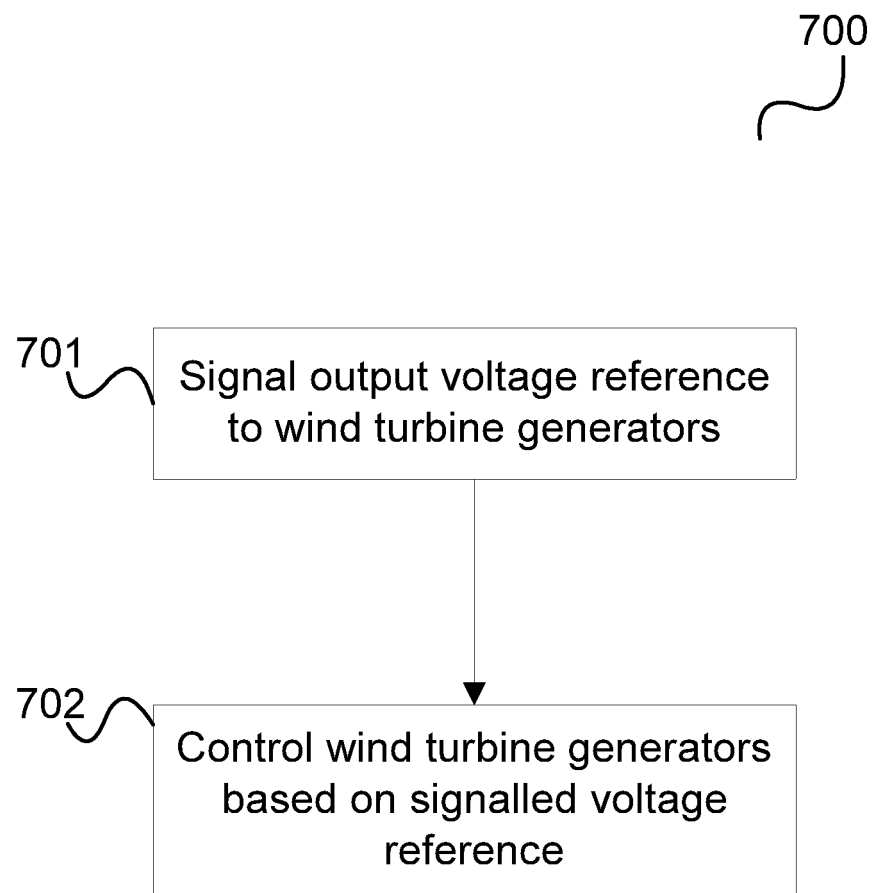


FIG 7



800

FIG 8

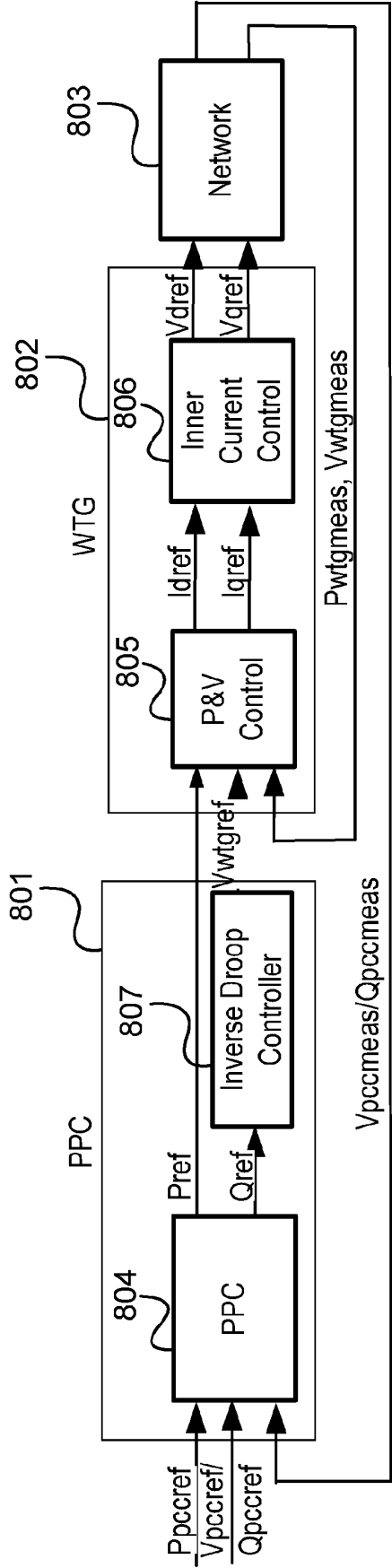
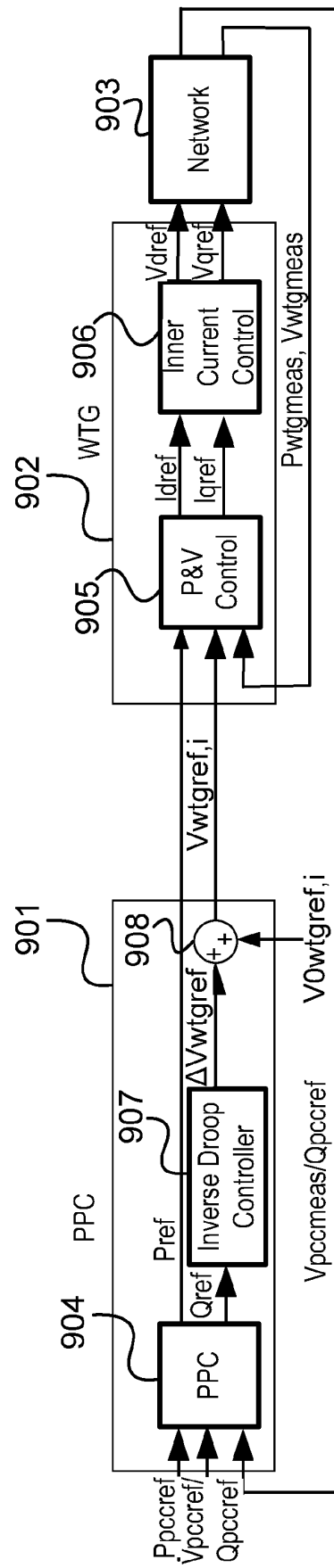


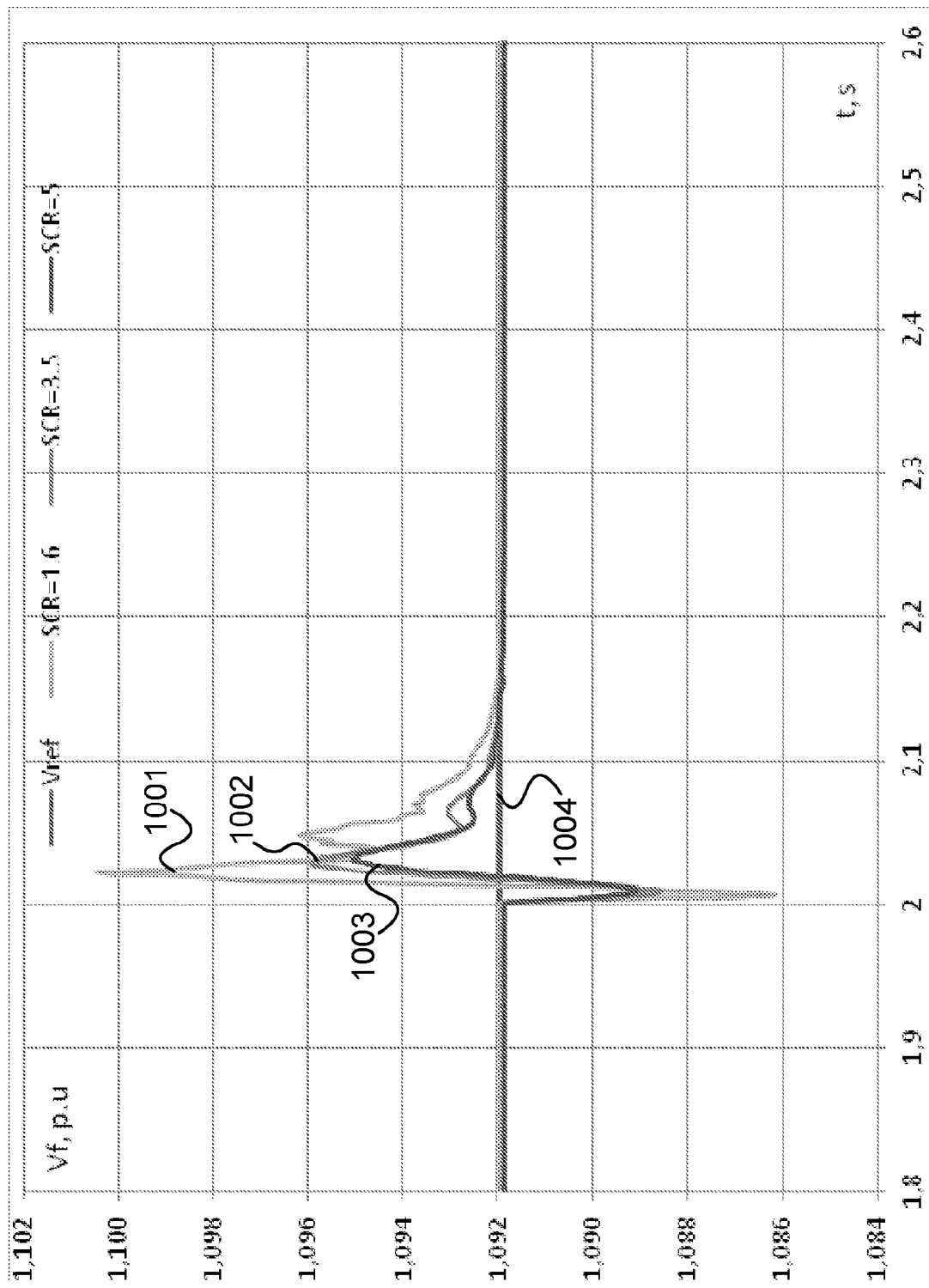
FIG 9

900



1000

FIG 10



REFERENCES CITED IN THE DESCRIPTION

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